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Tick surveillance of small mammals captured in Gyeonggi and Gangwon Provinces, Republic of Korea, 2004–2008

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Abstract

A total of 4,575 ticks were collected from 5,953 small mammals captured from March 2004 to December 2008 at 19 military training areas and 6 US military installations, Gyeonggi and Gangwon Provinces, Republic of Korea. *Ixodes nipponensis* (98.9%; 753 nymphs, 3,771 larvae) was the most frequently collected tick, found on six of the 11 small mammal species captured, followed by *Ixodes pomerantzevi* (1.1%; 17 females, 9 nymphs, 24 larvae) found on two species. While only one *T. sibiricus* was collected, it was infested with 44 ticks, with an infestation rate of 100.0%, followed by *Rattus norvegicus* (16.7%, n=18), *Apodemus agrarius* (14.6%, n=5,397), *Crocidura lasiura* (7.5%, n=265), *Microtus fortis* (7.3%, n=82), *Myodes regulus* (5.7%, n=53), and *Micromys minutus* (4.8%, n=63). No ticks were collected from *Apodemus peninsulae* (n=3), *Mus musculus* (n=58), *Tscherskia triton* (n=12), and *Mogera wogura* (n=1). *Ixodes nipponensis* nymphs were most frequently collected from small mammals from March to April, while larvae were more frequently collected during September. *Ixodes pomerantzevi* was collected only during February-April 2008, and a single *Haemaphysalis flava* nymph was collected from *A. agrarius* in August 2004.

Key words: *Ixodes nipponensis, Ixodes pomerantzevi, Haemaphysalis flava,* hosts, distribution, seasonality

Introduction

In the Republic of Korea (ROK), small mammals (e.g., rodents and insectivores) and their associated ticks are hosts to a number of zoonotic pathogens: spotted fever group rickettsiae (Lee *et al*. 2003), *Ehrlichia* and *Anaplasma* spp. (Chae *et al*. 2003), *Bartonella* spp. (Kim *et al*. 2005), *Borrelia burgdorferi* (Park *et al*. 1992, Kee *et al*. 1994), and tick-borne encephalitis virus (Kim *et al*. 2008, 2009). Man is an incidental host as a result of agricultural, outdoor construction and maintenance, military, and recreational activities. New information, including retrospective febrile patient surveys, indicates that tick-borne diseases are underdiagnosed in the ROK (W.J. Jang, unpublished data) and should be considered for inclusion in the Korea Center for Disease Control and Prevention's list of reportable diseases.

As a result of the Saemaul Undong (New Village Movement) and the Korean government's 1973-1987 green plantation program (Lee & Lee 2002), cultivated and unmanaged groves of deciduous, coniferous (pine, larch, cypress, cedar, fir) and mixed forests adjacent to often unmanaged grassy and vegetative areas have created additional habitats for various small and large mammal populations that serve as reservoir hosts of zoonotic pathogens and their associated tick

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14. ABSTRACT

A total of 4,575 ticks were collected from 5,953 small mammals captured from March 2004 to December 2008 at 19 military training areas and 6 US military installations, Gyeonggi and Gangwon Provinces, Republic of Korea. Ixodes nipponensis (98.9%; 753 nymphs, 3,771 larvae) was the most frequently collected tick, found on six of the 11 small mammal species captured, followed by Ixodes pomerantzevi (1.1%; 17 females, 9 nymphs 24 larvae) found on two species. While only one T. sibiricus was collected, it was infested with 44 ticks, with an infestation rate of 100.0%, followed by Rattus norvegicus (16.7%, n=18), Apodemus agrarius (14.6% n=5,397), Crocidura lasiura (7.5%, n=265), Microtus fortis (7.3%, n=82), Myodes regulus (5.7%, n=53), and Micromys minutus (4.8%, n=63). No ticks were collected from Apodemus peninsulae (n=3), Mus musculus (n=58), Tscherskia triton (n=12), and Mogera wogura (n=1). Ixodes nipponensis nymphs were most frequently collected from small mammals from March to April, while larvae were more frequently collected during September. Ixodes pomerantzevi was collected only during February-April 2008, and a single Haemaphysalis flava nymph was collected from A. agrarius in August 2004.

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vectors. On forested hillsides and in mountains and river valleys, outdoor activities occur year round but especially during the months when ticks are active, exposing human populations to all life stages of ticks and their pathogens. Military populations are at increased risk for acquiring tick-borne infections because they often conduct training operations in unmanaged areas where small mammals (e.g., rodents, insectivores, rabbits, and weasels), large mammals (e.g., deer, wild pigs, raccoon dogs, feral dogs, and cats) and pathogen-infected ectoparasites are present.

The purpose of the present study was to determine the relative abundance of ticks associated with small mammals at ROK- and US-operated military training sites and US installations in the ROK as part of the Eighth US Army tick- and rodent-borne disease surveillance program.

Materials and methods

Survey Area

Rodent-borne disease surveillance was conducted at 25 ROK- and US-operated military training sites/military installations, Gyeonggi and Gangwon Provinces, from 2004 to 2008 (Fig. 1). At training sites, trap lines were established adjacent to maneuver courses, firing positions, and perimeters of military ranges because these areas provided habitat (vegetative ground cover and food) for small mammals and did not interfere with training activities. At installations, trap lines were set within uncut grass and vegetative margins adjacent to areas of human activity, such as housing, airfields, open or forested parks, a golf course, water retention areas, and unmanaged lands.

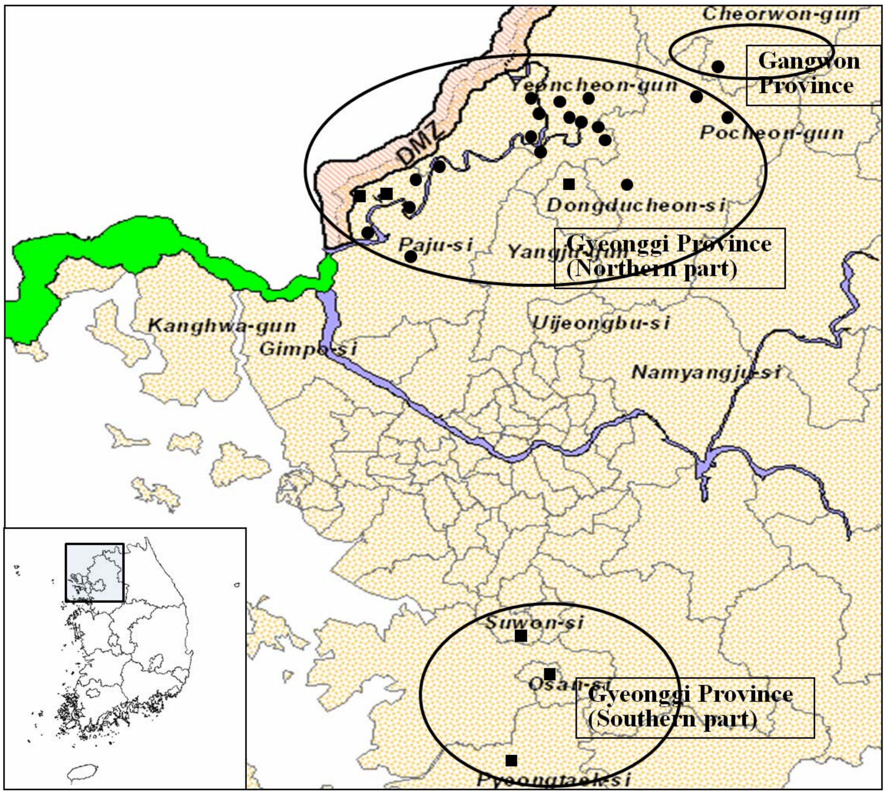

FIGURE 1. Collection localities for small mammals from military training sites (●) and installations (■) in northern and southern Gyeonggi and northwest Gangwon Provinces, Republic of Korea, 2004–2008.

Small mammal and tick collections

Sherman® traps (7.7 x 9 x 23 cm aluminum folding traps; H.B. Sherman, Tallahassee, FL), baited with peanut butter placed between two saltine crackers, were set out quarterly for 2 nights at selected training sites/installations. Lines consisting of 25 traps were set at 4–5 m intervals during daylight hours (1000–1800 hrs) and collected the following morning (0730–1100 hrs), as described by O'Guinn *et al.* (2008). Cotton balls (3–4) were added to each trap during the spring and winter trapping periods when temperatures were often <0^{o}C so that animals would retain heat and associated ectoparasites (e.g., fleas, mites, and ticks). Traps positive for small mammals were numbered sequentially, placed in a secure plastic shipping container, and transported to Korea University, Seoul, where the mammals were euthanized in accordance with an approved animal use protocol, identified to species, and given a unique identification number. Ticks were carefully removed with a fine forceps, placed individually in cryovials containing 100% ethyl alcohol, and labeled with a unique identification number that corresponded to the small mammal collection data. Ticks were sent to the 5th Medical Detachment, 168th Multifunctional Battalion, 65th Medical Brigade, Yongsan Army Garrison, Seoul, where they were identified to species and developmental stage under a stereomicroscope using standard keys and current nomenclature (Yamaguti *et al.* 1971, Robbins & Keirans 1992, Horak *et al.* 2002). An electronic data sheet was prepared that included unique host species and tick identification numbers, tick species, stage of development, date of collection, and geographical reference data.

Results

A total of 5,953 small mammals, representing 11 species in 10 genera, were captured at 19 military training sites and six US military installations from March 2004 to December 2008; all were examined for the presence of ectoparasites (fleas, mites, and ticks). *Apodemus agrarius* (Pallas) (n=5,397, 90.7%) was the most frequently collected small mammal, followed by *Crocidura lasiura* Dobson (n=265, 4.5%), *Microtus fortis* Büchner (n=82, 1.4%), *Micromys minutus* (Pallas) (n=63, 1.1%), *Mus musculus* Linnaeus (n=58, 1.0%), *Myodes regulus* (Thomas) (n=53, 0.9%), *Rattus norvegicus* (Berkenhout) (n=18, 0.3%), *Tscherskia triton* (de Winton) (n=12, 0.2%), *Apodemus peninsulae* (Thomas) (n=3, <0.1%), *Mogera wogura* (Temminck) (n=1, <0.1%), and *Tamias sibiricus* (Laxmann) (n=1, <0.1%) (Table 1).

Ixodes nipponensis Kitaoka and Saito (98.9%) was the most frequently collected tick, followed by *Ixodes pomerantzevi* Serdyukova (1.1%), and *Haemaphysalis flava* Neumann (<0.1%). While only one *T. sibiricus* was collected, it was infested with 44 ticks, with an infestation rate of 100.0%, followed by *A. agrarius* (93.0%), *R. norvegicus* (16.7%), *A. agrarius* (14.6%), *C. lasiura* (7.5%), *M. fortis* (7.3%), *M. regulus* (5.7%), and *M. minutus* (4.8%) (Table 1). No ticks were collected from *A. peninsulae*, *M. musculus*, *T. triton*, or *M. wogura*.

Eighteen of the military training sites and half (3) of the US military installations surveyed were located in northern Gyeonggi Province and had the highest tick infestation rate (16.5%), followed by US military installations (3) in southern Gyeonggi Province (2.8%), and the military training site (elevation 480–520 m) in northwestern Gangwon Province (2.3%), near the DMZ (Fig. 1, Table 2). The seasonal prevalence of *I. nipponensis* larvae collected from small mammals caused large spikes in the mean number of ticks collected in September (Fig. 2). *Ixodes nipponensis* nymphs were most frequently collected from small mammals from March to April, while larvae were more frequently collected from small mammals during the September surveys (Fig. 3). *Ixodes pomerantzevi* was collected only during February-April 2008, and only one *H. flava* nymph was collected from *A.*

agrarius in August 2004. No adult *I. nipponensis* or *H. flava* were collected from the small mammals.

TABLE 1. Number of small mammals and number of ticks collected, by stage of development, for each species of small mammal captured by Sherman® traps at selected military training sites and installations, Gyeonggi and Gangwon Provinces, Republic of Korea, 2004–2008.

Host/ Species	Total No small mammals	Small mammals w/ticks	*I. nipponensis*		*I. pomerantzevi*			*H. flava*	**Total Ticks**
			Larva	Nymph	Larva	Nymph	Adult	Nymph	
Apodemus agrarius	5,397	786 (14.6)[a]	3,523 (4.5)[b]	726 (0.9)[b]	0 (<0.1)[b]	4 (<0.1)[b]	2 (<0.1)[b]	1 (<0.1)[b]	4,256 (93.0)[c]
Apodemus peninsulae	3	0	0	0	0	0	0	0	0
Micromys minutus	63	3 (4.8)[a]	0	3 (1.0)[b]	0	0	0	0	3 (<1.0)[c]
Rattus norvegicus	18	3 (16.7)[a]	1 (0.3)[b]	6 (2.0)[b]	0	0	0	0	7 (<1.0)[c]
Mus musculus	58	0	0	0	0	0	0	0	0
Microtus fortis	82	6 (7.3)[a]	47 (7.8)[b]	4 (0.7)[b]	0	0	0	0	51 (1.1)[c]
Tscherskia triton	12	0	0	0	0	0	0	0	0
Myodes regulus	53	3 (5.7)[a]	0	3 (1.0)	0	0	0	0	3 (<1.0)[c]
Crocidura lasiura	265	20 (7.5)[a]	200 (10.0)[b]	11 (0.6)[b]	0	0	0	0	211 (4.6)[c]
Mogera wogura	1	0	0	0	0	0	0	0	0
Tamias sibiricus	1	1 (100.0)[a]	0	0	24 (24.0)[b]	5 (5.0)[b]	15 (15.0)[b]	0	44 (1.0)[c]
Total	5,953	822	3,771	753	24	9	17	1	4,575
		13.8%[a]	98.9%[d]		1.1%[d]			<0.1%[d]	

[a] Infestation rate (%) = (Total number of small mammals with ticks (by species)/Total number of small mammals captured (by species)) x 100.
[b] Mean number ticks = Total number of ticks collected from small mammals/Total number of small mammals infested with ticks, by species.
[c] Percent of total ticks collected for each species of small mammal captured.
[d] Percent of species collected = Sum of all ticks collected by species/total ticks collected during this study.

TABLE 2. Number of ticks collected from small rodents captured in three areas at selected military training sites and installations, Gyeonggi and Gangwon Provinces, Republic of Korea, 2004–2008.

Collection areas	Total No small mammals	Small mammals w/ticks	*I. nipponensis*		*I. pomerantzevi*			*H. flava*	Total
			Larva	Nymph	Larva	Nymph	Adult	Nymph	
Gyeonggi Province (Northern)	4,781	790 (16.5)[a]	3394 (4.3)[b]	741 (0.9)[b]	24 (<0.1)[b]	7 (<0.1)[b]	17 (<0.1)[b]	1 (<0.1)[b]	4184 (91.5)[c]
Gyeonggi Province (Southern)	1,084	30 (2.8)[a]	377 (12.6)[b]	12 (0.4)[b]	0	0	0	0	389 (8.5)[c]
Gangwon Province (Western)	88	2 (2.3)[a]	0	0	0	2 (1.0)[b]	0	0	2 (<0.1)[c]
Total	5,953	822 13.8%	3,771	753	24	9	17	1	4,575
			98.9%[d]			1.1%[d]		<0.1%[d]	

[a] Infestation rate = (Total number of small mammals with ticks (by collection area)/Total number of small mammals captured (by collection area)) x 100.
[b] Mean number ticks = Total number of ticks collected from small mammals (by species)/Total number of small mammals infested with ticks (by species).
[c] Percent of total ticks collected from small mammals for each area.
[d] Percent of total ticks, by species, collected from all small mammals.

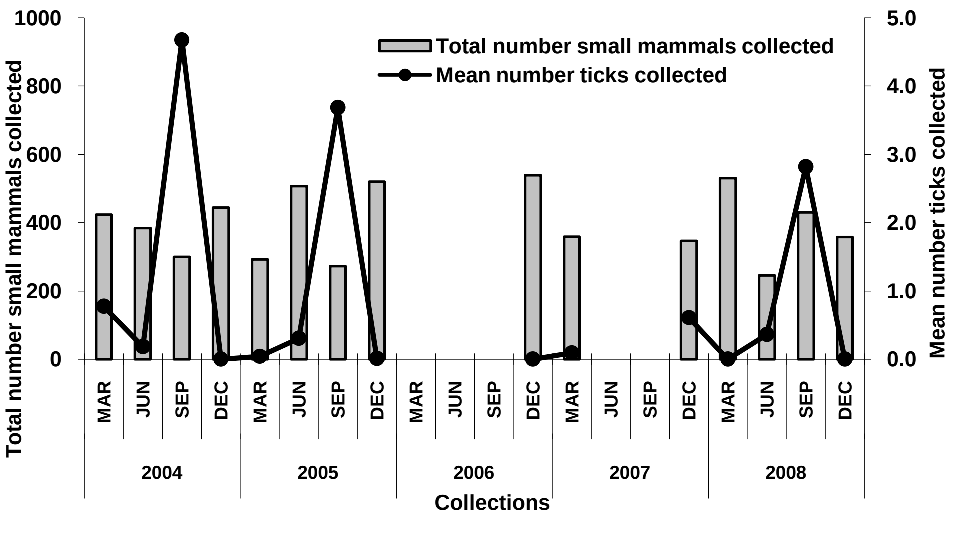

FIGURE 2. Mean number of *Ixodes nipponensis* larvae and nymphs collected from small mammals at military training sites and installations, Gyeonggi and Gangwon Provinces, Republic of Korea. Not shown are *Ixodes pomerantzevi* (50) collected during February–April 2008 and *Haemaphysalis flava* (1) collected during August 2004.

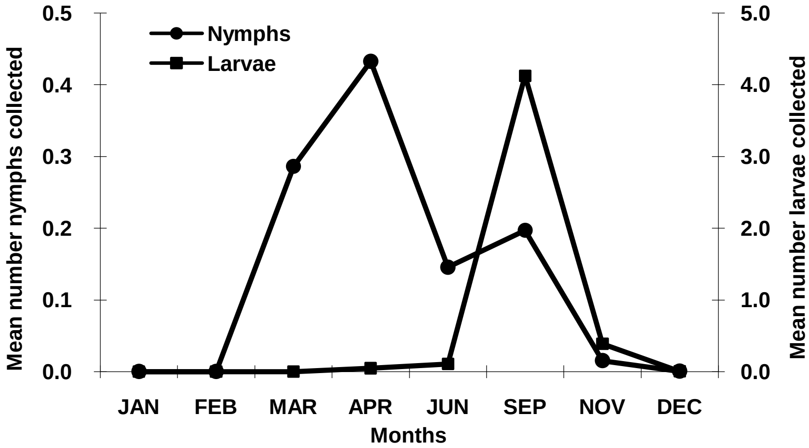

FIGURE 3. Mean number of *Ixodes nipponensis* collected by stage of development from military training sites and installations, Gyeonggi and Gangwon Provinces, Republic of Korea. No ticks were collected from small mammals captured during May, July and October, and no small mammal collections were conducted during August.

Discussion

Rodent- and tick-borne zoonoses pose a serious health threat to US and ROK military populations throughout the ROK (Park *et al*. 1992, Shim *et al*. 1993, Chae *et al*. 2003, Lee *et al*. 2003, Jang *et al*. 2004, Kim *et al*. 2005, Kim *et al*. 2008, 2009). Rodent-borne disease surveillance, including identification of arthropod ectoparasites and pathogens, can provide a picture of the relative abundance of small mammals and their habitats, together with epidemiologically important data on the host preference, stage of development, and seasonal distribution of associated ectoparasites. Such information is critical in any attempt to depict the prevalence and distribution of endemic and emerging zoonoses affecting humans in the ROK. For US and ROK military populations, which often train in rodent-infested areas, these data are central to the development of disease risk assessments and mitigation strategies (e.g., use of insecticide-impregnated uniforms) aimed at reducing the impact of zoonotic diseases while increasing awareness among medical providers of potential arthropod-borne infections. Additionally, such data permit estimates of the potential for transmission of zoonotic pathogens among civilian populations residing in rural and urban environments or conducting agricultural, construction, recreational, and other outdoor activities where arthropod ectoparasites are found.

The two primary methods of tick collection are removal of ticks from domestic and wild animals and tick drags. The proportion of *I. nipponensis* collected from tick drags in Gyeonggi Province was <20%, but it was the most common tick (98.9%) collected in this study. In other reports, *I. nipponensis* was the most frequently collected tick from small mammals captured in Gyeonggi Province, while *Ixodes persulcatus* Schulze was the most commonly collected tick in Gangwon Province (Shim *et al*. 1992, 1993). Although *I. persulcatus* was the most frequently collected tick from small mammals in Pyeongchang-gun (county) and Yangyang-gun, in eastern Gangwon Province (Shim *et al*. 1992), our collection site was situated in western Gangwon Province, on the western slopes of the Taebaek mountain range; collection sites where *I. persulcatus* was commonly collected were within and east of this range. Larvae and nymphs of *Ixodes nipponensis* feed on small mammals; adults feed on larger animals. In this survey, only *I. nipponensis* larvae and nymphs were collected from small mammals captured throughout the year. Because few *Haemaphysalis* spp. have been reported from small mammals, *I. nipponensis* appears to be the most likely vector of tick-borne zoonoses observed in rodents and insectivores captured in Gyeonggi and western Gangwon Provinces. Similarly, *I. nipponensis* may play an important role in the transmission of tick-borne pathogens to humans in the ROK because this species is more frequently reported from patients (Lee *et al*. 1989, Ryu *et al*. 1998, Ko *et al*. 2002, Chang *et al*. 2006).

Ixodes pomerantzevi is an uncommon tick that was collected only from February through April and in areas of higher elevation (>100-520 m) in northern Gyeonggi and Gangwon Provinces (Kim *et al.* 2009b). Attempts to collect this tick on drags in areas where it was collected from *A. agrarius* were unsuccessful, and of >20,000 ticks taken from tick drags as part of the US military tick-borne disease surveillance program throughout Gyeonggi and Gangwon Provinces (mostly <100 m in elevation), no *I. pomerantzevi* were found. All previous collection records of *I. pomerantzevi* were of specimens removed from small mammals (*M. regulus*, *T. triton*, and *T. sibiricus*) while conducting routine surveys at elevations >100 m (Robbins & Keirans 1992, Anonymous 1997, Ree 2005, Kim *et al.* 2009b).

Haemaphysalis spp. are the most commonly collected ticks on drags, accounting for >80% of all ticks collected in surveys conducted as part of the US military tick-borne disease surveillance program in Gyeonggi Province. *Haemaphysalis flava* nymphs and adults are found on a variety of small to large mammals, larvae and nymphs often being associated with rodents and birds (Yamaguti *et al*. 1971, Kim *et al*. 2009a). Although >4,500 *I. nipponensis* were collected from >5,000 rodents and insectivores in this study, only one *H. flava* was found. In the ROK, preliminary evidence suggests that *H. flava* is more characteristic of forested habitats; rodent trapping in forested habitats was very limited during our study, and this may account for the virtual absence of *H. flava* on captured small mammals (unpublished data). In Japan, *Haemaphysalis* spp. were found to be very abundant in field and forested environments, where *H. flava* is considered an important vector of tularemia (Yamaguti *et al*. 1971).

Further studies of tick-host relationships are necessary to better understand tick species distributions and population dynamics, the distribution and prevalence of tick-borne pathogens, and their potential effects on human and animal health.

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